

Antennæ brownish towards the apex, stout, and placed close to the top of the clypeus. Head rather long and flat and wider than the thorax; the eyes are almost parallel; the ocelli in a curve (· · ·) and separated from the eyes by about the same distance they are from each other. Clypeus short, its apex transverse. Mandibles rufous, black at the apex; the base thickly covered with depressed silvery pubescence. Pronotum large, but not quite so long as the head; it is depressed at the base, transverse at the apex. The entire thorax is thickly covered with depressed silvery pubescence; its apex has an oblique slope. Wings short, not reaching to the apex of the second abdominal segment, yellowish hyaline, the apex near the middle of the radial cellule infuscated; the radius is roundly curved from base to apex; the second and third cubital cellules are equal in length above and beneath; the first transverse cubital nervure has an oblique slope on the upper half; the first recurrent nervure is received shortly behind the second, beyond the middle of the cellule; the transverse median nervure is received at a distance—by about its own length—beyond the transverse basal; the anal nervure in the hind wing is appendiculated. Legs densely pruinose, the tibiæ bare, the tarsi bearing thick spines, the claws bifid. Abdomen with the segments bordered with silvery pubescence; it is about as long as the head and thorax united; the second ventral segment has a transverse furrow.

The presence of a transverse furrow on the second (or third according to one method of counting, the first segment forming part of the median segment) brings this species into Bingham's section "*B. Ferreola* Group." It has certainly no near relationship beyond the abdominal furrow to such species as *P. Cameronii*, Bingh. (*fenestrata*, Bingh., nec Smith). The present species has some resemblance to the *Pompilus vivax* group, but is easily known from them by the abdominal furrow, by the transverse basal nervure being widely remote from the transverse median, and by the short wings.

LXXI.—*Plankton Studies*.—III. On *Platydorina*, a new Genus of the Family *Volvocidæ* from the Plankton of the Illinois River. By C. A. KOFOID, Ph.D.*

[Plate VII.]

THE family *Volvocidæ* is well represented in the plankton of freshwater ponds and streams. Indeed, with the possible

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exception of *Stephanosphaera*, all of the colonial forms included in the subfamily Volvocinæ—*Spondylomorom*, *Gonium*, *Stephanosphaera*, *Pandorina*, *Pleodorina*, and *Volvox*—are pelagic in habit and are found only in the freshwater environment. For the past four years, during the summer and autumn months, a colonial form belonging to this subfamily has occurred in plankton collections from the Illinois River and its adjacent waters, to which I have given the name of *Platydorina caudata*. It appears as early as June 15, and becomes abundant in the months of August and September, diminishing in numbers in October, and disappearing in November. It thus attains its greatest development toward the close of the maximum period of summer heat, when the temperature of the water in which it is found often reaches 36° C. This species has occurred in all the waters examined in the course of the operations of the Illinois Biological Station, viz. in the Illinois River, in Thompson's, Quiver, Flag, Matanzas, and Phelps Lakes, at Havana, Ill., and in the Illinois River and Meredosia Lake at Meredosia, Ill. During the summer and fall of 1899 it was also found in abundance near Urbana, Ill., in Salt Fork, a small stream tributary to the Vermilion River—a confluent of the Wabash. It was not equally plentiful in all these localities, but showed a decided preference for shallow water free from vegetation, reaching its maximum development when the turbid water was but a few feet, or even less than a foot, deep. In such situations the shallowness of the water and the absence of vegetation conduce to a maintenance of the high temperatures which seem to favour its multiplication. The bottom of the lakes in question is usually composed of soft mud, rich in decaying organic matter, and often covered by a mat of *Oscillaria*, but otherwise quite free from vegetation. At Havana we have found *Platydorina* in greatest numbers in Phelps Lake, which in 1896, 1897, and 1898 afforded the conditions above described. It was likewise abundant in Thompson's Lake in the late summer and early fall of 1897 and 1898, when the lake was at a low level and contained little vegetation. In the shallow open waters of Matanzas Lake it was much more abundant than in Quiver Lake, where there was usually a large amount of vegetation. At the time of the maximum abundance of *Platydorina* in Salt Fork in September the stream was reduced by drought to a series of stagnant pools with no vegetation. In the early part of August it was full of algæ and other aquatic vegetation, and *Platydorina* was then present in considerable numbers, although not so abundant as it was in the following month.

On August 2, 1888, Professor H. Garman, while conducting a biological survey of the aquatic life in the vicinity of Quincy, Ill., in the bottoms of the Mississippi River (see Garman, 1890), found a specimen of this interesting species in the waters of Libby Lake. He records and sketches it in notes now on file at this Laboratory, but published nothing concerning it.

The occurrence of this new genus in the waters of the Wabash, Illinois, and Mississippi River systems, and its recurrence in our collections for several successive years indicate its wide distribution and firm establishment in the Mississippi Valley in waters of some permanency. It has not yet been noted in temporary pools.

The associates of *Platydorina* in the plankton have varied with the season, the locality, and the year. It may be said, in a general way, that the plankton in which it occurs is characterized by an abundance of flagellates, of rotifers—especially *Brachionidæ*—and of immature Copepoda. A water-bloom, composed largely of *Euglena*, *Trachelomonas*, *Carteria*, and other green flagellates, often appears at the surface of waters where *Platydorina* is abundant. *Gonium* is frequently associated with it in large numbers, as are also *Pandorina*, *Eudorina*, and *Pleodorina*, though these three genera may also be plentiful in the early summer, when *Platydorina* may be absent or rare. *Pleodorina californica* was extremely abundant in Salt Fork in August, but had almost entirely disappeared by the time that *Platydorina* had reached its maximum. A few specimens of *Volvox*, which, in this locality, is common in the spring months, were also noted, while perhaps the most interesting associate in Salt Fork was *Ceratium kumaonense*, discovered by Carter (1871) in Hindostan. Other chlorophyll-bearing associates frequently seen are *Pediastrum*, *Scenedesmus*, *Actinastrum*, and *Closterium*. Among the diatoms, *Melosira*, *Fragillaria*, and *Surirella* were to be seen; and among the Peridinidæ *Peridinium tabulatum* was almost always represented.

The zoöplankton associated with *Platydorina* is not less varied than the phytoplankton. The Protozoa were usually represented by *Arcella*, *Difflugia*, and occasionally by pelagic *Amæba*; by *Synura*, *Mallomonas*, *Dinobryon*, and *Uroglena*; and by *Codonella* and *Coleps*. Among the Rotifera the order Ploima was well represented; *Triarthra* and the *Brachionidæ*—notably *Brachionus militaris*, *B. angularis*, *B. punctatus*, and *B. Bakeri* and its varieties—were most common during the summer months, while the *Synechætidæ* increase in numbers in the early autumn. *Polyarthra* was frequently abundant,

and *Rotifer*, *Philodina*, *Asplanchna*, *Euchlanis*, *Cathypna*, *Distyla*, *Monostyla*, and *Pterodina* were often represented by one or more species. The paucity of Entomostraca stands in sharp contrast with the abundance of rotifers, the former group being represented by relatively few species and few adult individuals. The nauplii of *Cyclops* were, however, as a rule, abundant, but only occasional specimens of adult *Cyclops*, *Diatomus*, *Bosmina*, *Chydorus*, *Ceriodaphnia*, *Daphnia*, and *Cypridopsis* were to be seen.

Platydorina caudata, gen. et sp. n.

The species here described consists of a horseshoe-shaped cœnobium or colony (Pl. VII. fig. 1) of 16 or 32 biflagellate cells, the anterior end corresponding to the toe of the horseshoe and the truncate posterior end to the heel, the latter carrying 3 or 5 prolongations or tails formed by the gelatinous substance of the cœnobium. The colony is plate-like and flat, except that the plate is slightly twisted in a left spiral. This spiral is scarcely noticeable in a face view (fig. 1) except by focussing with a high-power objective, but it can be easily detected in a side view (fig. 3). It varies from one eighth to one thirty-second of a turn of the spiral, and in twenty-five colonies especially examined on this point it was invariably a left spiral, with the location of the twisting always in a definite relation to the colony, the right anterior and the left posterior regions of the colony in face view being high, while the left anterior and the right posterior are low. Repeated examinations of specimens, both living and preserved, indicate that this spiral form is a constant feature of structure, that it is not reversed in direction, and that it is subject to but slight variation in the degree of the torsion. No movement within the colony which would produce or vary the spiral was noted in living individuals. The form of *Platydorina* seems to be as constant and as characteristic as that of other genera of the family.

The size of the colony varies with the age, with the number of cells present, and also perhaps with the locality and the season. Colonies of 32 cells in which the first division leading to the formation of daughter colonies is taking place average about 150 μ in length, 130 μ in width, and 20 μ in thickness. The largest colonies are about 165 \times 145 \times 25 μ , and the smallest free-swimming ones about 25 \times 21 \times 4 μ . Colonies of 16 cells are smaller than those of 32 cells and are also narrower in proportion to their length, measuring about 70 \times 43 \times 16 μ .

The colours of *Platydorina* are quite as striking as those of related forms. The cells, which are imbedded in the transparent gelatinous matrix of the colony, are a bright chlorophyll-green, and each has, as a rule, a red stigma or eye-spot of unusual brilliancy.

The substance in which the cells of the colony are imbedded is similar in appearance to that in *Eudorina*. It is a transparent colourless substance of considerable consistency, showing in the living condition, as a rule, no trace of differentiation. The gelatinous nature of the substance is shown by the great numbers of bacteria which swarm within it in moribund specimens. Colonies killed in formalin and stained in Delafield's hæmatoxylin exhibit a difference in the intensity of coloration, indicating the presence of a denser peripheral layer or sheath 3-4 μ in thickness (Pl. VII. figs. 1, 4, *p.sh.*). This is apparent along the edges of the colony and presumably extends over its faces. In several living colonies a granular differentiation of this outer layer was noted about the margin. This sheath is similar to that of *Eudorina* and *Pleodorina*, but shows no trace of the concentric layers so prominent in *Pandorina*.

One of the most characteristic features of the colony is the presence upon the posterior border of 3 or 5 projections or tails, which are merely extensions of the sheath. Colonies of 16 cells have but three tails, while those of 32 cells have uniformly five. These projections are bluntish finger-like processes without structural differentiation, tapering somewhat to a rounded or pointed end. Occasionally the outermost pair, and more rarely the inner one, are slightly divergent. In the 16-cell colony there are two latero-posterior tails and one median one (fig. 2), the former being better developed and measuring 15 to 20 μ in length. The median tail is variable in length, being sometimes a mere rudiment appearing on a slight elevation on the margin. Its average length is about one third that of the adjacent pair, though it occasionally attains two thirds their length. The latero-posterior tails are upon each side of the colony directly behind the marginal row of cells, while the median tail is midway between the central rows. In the 32-cell colony (fig. 1) there is, in addition to the three tails above noted, another pair which may be designated as the lateral pair. These tails are slightly divergent, arising at the outer posterior angles of the marginal row of cells, between the last transverse quartet and the last sextet of cells. They are from 10 to 15 μ in length and are often of the same size as the median tail of the colony. The other three tails occupy the same position with respect to the

posterior quartet of cells that they do in the 16-cell colony, but are, as a rule, much larger, the postero-lateral pair measuring from 20 to 30 μ in length, while the median one reaches only a length of 15 to 18 μ . The five tails do not lie in one plane, but share in the spiral of the colony, at times, indeed, exceeding it in the degree of the twisting. These structures are all subject to considerable variations and irregularities of development (fig. 5), such as suppression, inequality of members of pairs, differences in size and relative development, in attenuation, and in degree of divergence. These irregularities are often correlated with the loss of cells in the colony due to parasites or other causes. The tails nevertheless exhibit such a constancy of position and so much of symmetry and regularity of development that they cannot for a moment be considered as ephemeral features of little structural importance. In their position they recall the protuberances noted by me (1898) at the posterior end of *Pleodorina illinoisensis*. In *Pleodorina*, however, these structures are apparent only in disintegrating maternal colonies, and it may be that they also indicate the point at which the embryonic cup closes. On the other hand, in *Platydorina caudata* these tails are present upon the colonies at the time of their escape from the maternal matrix, and persist throughout the life of the adult, being permanent structures, characteristic of the species.

Within the outer sheath is a homogeneous gelatinous matrix (fig. 1, *m*), which in Delafield's hæmatoxylin stains less readily than the sheath. In the living colony no differentiation of this matrix is to be seen, but, after staining, a delicate sheath showing deeper colour is demonstrated about each of the cells. In most places a considerable space intervenes between this secondary sheath (fig. 4, *s.sh.*) and the inclosed cell, so that the sheaths crowd upon each other and appear to divide the field of the matrix into irregular polygonal areas. These areas, as a rule, fill the greater part of the plate, leaving unoccupied only a few corners, principally about the second transverse row. The two poles of this swollen secondary envelope are not of equal size, the inner being somewhat the smaller, and slightly overlapped by those of the contiguous cells. This is due to the intercalation of the cells of the two sides of the plate and to the fact that the outer ends of the cells are slightly nearer the surface of the plate than are the inner ones. The gelatinous substance within the secondary sheaths does not differ in structure or stainibility from that of the surrounding matrix. As a result of the form of the

colony the amount of the matrix substance is much less in *Platydorina* than in related forms such as *Eudorina*.

The cells of the colony are all of one type, alike in structure, and approximately similar in size. Each is bitlagellate and has a central body of protoplasm with a nucleus, two contractile vacuoles, one stigma, and one chromatophore with a single pyrenoid.

The number of cells in the colony is either 16 or 32; at least no normal colony with cells of any other number has been detected among the hundreds, if not thousands, of colonies examined. Colonies are frequently seen which, by reason of parasites or from other causes, have lost one or more cells—indeed, in some cases all but one or two; but the form of these colonies is usually preserved, and the empty secondary sheaths frequently remain as evidence of the original complement of cells. The 16-cell colonies are not mere stages in the development of the 32-cell form, for division of the cells of this type in observed cases leads to the development of new colonies and not to the formation of the 32-cell stage. As in other nearly related genera of the family—for example, *Eudorina*, *Pandorina*, and *Pleodorina*—the number of cells in the colony varies, within narrow limits, in the ratio of geometrical progression. In *Platydorina*, however, this pleomorphism is manifested not only by this difference in the number of cells in the colony, but also by a structural distinction—the presence of three tails in the 16-cell and five tails in the 32-cell colony. Inasmuch as the two types always occur together, and since this pleomorphism is in some respects similar to that of related genera, it does not seem justifiable to regard the two as distinct species of the genus. They are, I believe, two forms of one species.

The arrangement of the cells is characteristic and is strikingly different from that of any other genus of the family. The gelatinous matrix and sheath conform to the horseshoe-shaped plate of cells, and even the caudal appendages bear a fixed relation to the plan of cell-arrangement. The 32-cell colony is composed of a marginal U-shaped row of 12 cells about three sides of a 20-celled somewhat rectangular plate, which, in turn, consists of an outer row of 12 cells on three sides of a row of four pairs of cells. The colony might also be regarded as made up of three U-shaped rows of 12, 12, and 8 cells respectively, nested in such a fashion that the inner two project one cell beyond the outermost. The cells also fall into six quite irregular transverse rows of 4, 6, 6, 6, 6, and 4 cells respectively, and into the same number of corre-

sponding longitudinal ones. As before stated, the lateral tails are posterior to the marginal row, while the postero-laterals are behind the first row within the marginal, and the median one midway between the innermost rows. In the colony of 16 cells (fig. 2) the marginal row has but 10 cells and the central plate but 6. The cells fall into four somewhat irregular transverse rows, and there are the same number of longitudinal ones of 4 cells each. The horseshoe-shape, however, masks somewhat this simple *Gonium*-like arrangement. The plate-like form of the colony and the arrangement of the cells, especially in the 16-cell form, give this new genus a superficial resemblance to *Gonium*. It is, however, fundamentally different, for in *Platydorina* the two faces of the plate are exactly alike, while in *Gonium* the face anterior in locomotion bears all the flagella, and the other face presents only the bases of the cells. This similarity of the two faces in *Platydorina*, neither of which is anterior or posterior, is brought about by the fact that every other cell upon either face presents to that face the pole which bears the stigma and the flagella, while the intervening cells present the opposite pole, with its pyrenoid. This alternation of stigma and pyrenoid is constant, and can be followed in any row of cells except the diagonal ones (cf. fig. 1). The cells of the marginal row, in both the 16- and 32-cell colonies, point obliquely outward, the direction alternating, however, in conformity with the arrangement of cells in the central area, as may be seen in a view of the edge of the colony (fig. 3). The alternation of the cells in the colony as a whole is the same whichever face is presented, the right-hand cell of the posterior row of four cells always presenting the basal end uppermost. From this as a starting-point the regular alternation of stigma and pyrenoid can be traced from cell to cell throughout the whole colony. An examination of twenty-five colonies showed that all conformed to the same plan of alternation, there being no case of reversal. In the arrangement of the cells in the colony *Platydorina* is thus more like *Eudorina* than like *Gonium*, being not a simple plate like the latter genus, but, in reality, a flattened ellipsoid so much compressed that the cells of the two faces intercalate regularly, and thus give to the colony its superficial resemblance to *Gonium*.

The individual cells are all substantially alike in size and structure. They have the form of an oblate spheroid, slightly larger in the outer hemisphere*. Some cells, especially the

* As in the case of *Eudorina* and *Pleodorina* the terms "outer" and

marginal ones, often exhibit a slight flattening or even a depression at the outer pole. In the full-grown colony the cells have an equatorial diameter of 15-20 μ and a polar one of 15-18 μ . The cells of young colonies still within the maternal matrix do not exceed 4-6 μ in diameter. I do not find that the cells of the 16-cell colonies are appreciably larger than those of the 32-cell.

The protoplasm is small in amount, consisting of a very thin pellicle (fig. 4, *p.*) on the surface of the cell on the outside of the chromatophore, and an axially-placed knob-shaped mass (*pr.*) located somewhat nearer the outer pole than the inner one. Near the centre of this mass lies the spherical nucleus (fig. 4, *n.*), containing a single spherical nucleolus (*ncl.*). Within this protoplasmic mass lie the two contractile vacuoles (*c.v.*) and the stigma (*st.*), while from the outer end of the cell arise the two flagella (*f.*).

There is but a single cup-shaped chromatophore (fig. 4, *chr.*), which is inclosed within the pellicle above noted, and itself contains the knob-shaped protoplasmic mass. It is of a brilliant chlorophyll-green colour, and contains numerous small granules of irregular and somewhat angular outline. Towards the inner end of the cell, imbedded in the thickest part of the chromatophore, there is a single spherical pyrenoid, having a diameter of 4-6 μ .

The stigma or eye-spot, seen from above, is circular in outline, but in lateral view has the form shown in fig. 4, *s.* The slightly convex outer surface appears to project somewhat beyond the rounded contour of the cell. The colour is usually a bright reddish brown, often brightest in the anterior and marginal cells and rarely entirely faded in the posterior ones. The stigma is a homogeneous body, showing no trace of structure beyond the well-defined contour-line, which is best seen in fading and moribund cells. It is normally present in all cells of the colony, and may readily be demonstrated by full illumination. The position of the stigmata in the cells is somewhat unusual, and is significant of the pronounced polarity of the organism. The customary position in other genera is adjacent to the bases of the flagella. In *Platydorina*, however, the location of the stigma is not constant with respect to the flagella, but seems rather to bear a definite relation to the form of the colony, since it lies towards

"inner" are used to designate respectively the ends which bear the stigma and the pyrenoid.

the peripheral and posterior region of the cell (fig. 1), while the flagella are centrally located and project outward in the usual manner. This relation appears not only in the marginal regions, but also in the central. The physiological significance of this arrangement is not apparent, but it seems to be correlated with the pronounced polarity of the organism. *Platydorina* is positively phototactic. A miscellaneous plankton collection placed in a window with southern exposure in an aquarium 6 inches in diameter was, after ten minutes, quite barren of *Platydorina* except along the margin towards the window. On the other hand, this species avoids bright light. This was very evident in collections fresh from the field when examined under low power (75 diameters), a very slight increase above a moderate illumination causing them to leave the field of view with considerable rapidity. In one case, where twenty-eight colonies were in the field when placed under the microscope, only one of them remained after an exposure of twenty-five seconds. A very slight decrease in the amount of light would invariably insure their return to the field with almost equal rapidity, the number increasing as the intensity of the illumination was decreased. It may be that the asymmetrical position and the somewhat unusual arrangement of the stigmata are connected with the pronounced phototaxis of this organism. At least the asymmetrical position has a tendency to place the long axis of the stigma parallel to the main axis of the colony, with the outer end directed towards the source of light in negative, and away from it in positive, phototaxis.

The flagella are uniformly two in number for each cell, are similar in the same cell and in different parts of the colony, and are in the adult colony 20-25 μ in length. From the outer pole of the cell they pass through the matrix, leaving the appearance of a tube-like structure in the gelatinous substance (fig. 4). When not in activity the flagella project beyond the sheath in a position perpendicular to the surface of the colony at the place of exit. As in other genera of this family, the flagella persist after the division of the cell to form the daughter colony, and even after the divisions are completed still provide locomotion for the maternal organism. In some instances the flagella could be seen passing through the matrix toward that cell of the daughter colony which bears the largest eye-spot.

The contractile vacuoles (fig. 4, *c.v.*) are two in number, and are located in the peripheral layer of protoplasm near the outer end of the cell. They lie in the outer part of the knob-shaped mass of protoplasm upon either side of the place

of origin of the flagella, being somewhat widely separated. At diastole the vacuoles of an adult colony have a diameter of 1.5-2 μ . The contraction is rhythmical and the two vacuoles usually alternate at regular and equal intervals. At a temperature in the laboratory of 20° C. each vacuole contracted at intervals of forty-five to fifty seconds. In rare instances the contractions of the two vacuoles were separated by unequal intervals, being almost coincident in one case observed.

The method of locomotion in *Platydorina* is similar in many respects to that of other genera of the family. The lashing of the flagella produces a forward movement of the colony, and causes its rotation about the major axis either from left over to right or from right over to left. The rounded end of the colony is uniformly directed forward in locomotion; at least, no instance in which the caudal end led was noticed. The forward movement is, as a rule, accompanied by the rotation of the colony, though the amount of rotation varies somewhat with the individual, the freedom of movement, and the speed of locomotion. When locomotion is blocked by obstructions the rotation continues, as in *Pleodorina*, with frequent reversals in direction. In fact, obstruction to progress seems frequently, though not uniformly, to act as a stimulus to the reversal of the direction of rotation.

The two directions of rotation are not equally prevalent, that from right over to left having a marked predominance. Thus, of twenty-five colonies observed in motion twenty were rotating from right over to left and but five from left over to right. In another twenty-five the corresponding numbers were nineteen and six respectively. Keeping a single colony under observation for some time, it is found to rotate from right over to left about four fifths of the period and to turn in the opposite direction the balance of the time, this proportion representing the totals of the periods of rotation, while the individual periods vary greatly in length, that from left over to right lasting at times but a few seconds.

This predominance of one direction in locomotion is doubtless correlated with the torsion of the colony, whose shape is such that the rotation would necessarily be from right over to left in forward locomotion, as a result of the resistance of the water, unless, of course, there should be some disturbing factor. The immediate and most potent cause of the direction of rotation is doubtless the coordinated action of the flagella, since reversal of direction does not seem to be accompanied by any change in the direction of the torsion of the colony. The evidence upon this point is not conclusive, but repeated efforts have failed to detect any change in the

form of the plate when the direction of rotation is reversed in the living and moving colony; and, again, colonies when killed suddenly have always the usual form of spiral, though some of them were moving in the reverse direction. When the usual direction of rotation is reversed, the forward motion still continues in spite of the fact that then the form of the plate favours a backward movement; the form of the colony, therefore, does not control the direction of rotation, though it is correlated with the direction which predominates. The fact that the rotation from right over to left predominates also in *Pleodorina illinoisensis* and *Eudorina elegans*, where there are no structural features favouring such a predominance, suggests the possibility that the form of the colony in *Platydorina* is the result and not the cause of this predominance, and that the function of turning from right over to left predominantly preceded the structure which favours it. The organization of *Platydorina* suggests a descent from a *Eudorina*-like form, in which event the systematic series and the phylogenetic series alike afford evidence of a function arising in an organism before the structure with which it is correlated appears.

In another connexion (1898) the subject of locomotion and polarity in the different genera of the Volvocinæ was reviewed and discussed. It will suffice, therefore, for the present to give a brief résumé of the facts. In the lower genera of the family, *Stephanosphaera* and *Gonium*, as also in *Pandorina*, the rotation seems to be indifferently to the right or left, while in *Eudorina*, and especially in *Pleodorina illinoisensis*, it is oftenest to the left, rotations to the right in observed cases of the latter species being to those to the left as 100 to 117-138. With respect to *Volvox*, there are no data at hand. In *Platydorina* we find by far the most pronounced predominance of one direction of rotation, the ratio in observed cases being 100 rotations from left over to right to 355 from right over to left. In this respect, then, so far as there is evidence, *Platydorina* is the most highly differentiated genus of the family.

The polarity of the lower genera, *Stephanosphaera* and *Gonium*, is likewise of the simplest form, being merely physiological, the same pole or face of the colony always leading in locomotion. In *Pandorina*, *Eudorina*, and *Volvox*, however, there is the added feature of the greater brightness of the anterior stigmata, and in *Pleodorina* the two poles are differentiated by the two types of cells, as well as by the characters found in the genera just mentioned; but *Platydorina* is the only genus of the family in which polarity is

expressed by the arrangement of the cells and by structural features of the envelope. In regard to polarity, also, the new genus is thus the most highly specialized member of the *Volvocinae*.

The reproduction of *Platydorina* has been observed by me repeatedly in the past five years, but only the asexual phase has thus far been discovered. All of the cells of the organism are gonidial, each dividing to form a daughter colony. The sequence of the divisions and the position of the successive planes are of the type found in *Eudorina* and *Pleodorina*, the resemblance being so close that the figures illustrating the asexual development of *Pleodorina illinoisensis* (1898, pl. xxxvii.) might almost be used for cleavage in *Platydorina*. There is one difference, however, for in *Platydorina* the curved plate of cells, which becomes first cup-shaped and then ellipsoidal, subsequently flattens, the cells of the two faces intercalating during the process. The daughter colony acquires the adult form, including the tails and the torsion of the plate, before it escapes from the maternal matrix, the young colonies moving about for some time in the disintegrating matrix before making their escape through the ruptured outer sheath. The secondary sheath surrounding the gonidial cell becomes the outer or primary sheath of the new colony. No stages of sexual reproduction have been seen, though the collections examined represent a considerable range of season and locality. It may be that these are to be sought upon the bottom rather than in the superjacent strata of water where plankton collections are usually made. Aquaria about to dry up were also searched in vain for sexual stages of *Platydorina*.

The mode of development of *Platydorina* is significant of its systematic position and its relationships. The number and the original arrangement of the cells, the type of development, and the character of the envelope, all indicate that *Platydorina* is a more highly specialized form descended from some *Eudorina*-like ancestor, and that it is more closely allied to *Eudorina* than to any other existing genus.

Throughout this paper the customary term "colony" has been used to designate the organism herein described and others related to it. The wide use of the term in the literature of the subject is doubtless due to the fact that, as a rule, the organisms are composed of similar cells arranged in symmetrical form with no pronounced axial differentiation, without contact or protoplasmic connexion, separated from each other by a non-living gelatinous matrix, and each capable of performing all the functions necessary for its own life and the

continuance of the species. Furthermore, the destruction of individual cells does not impair the life of the other cells of the organism, for so long as a single cell remains it continues its customary activity. The use of the term colony is, however, objectionable. A number of facts militate against this conception of the organism, and the discovery of the new genus here described adds to the array. (1) The cells are not always similar, for in all forms with poles physiologically or otherwise differentiated the anterior stigmata are brighter than the posterior, and in *Pleodorina* there are two kinds of cells, the vegetative and the gonidial, the former distinctly smaller than the latter. (2) There is in all of the higher genera a well-defined physiological polarity accompanied by the difference in the anterior and posterior stigmata, and also, in *Platydorina*, by a differentiation of the poles by the arrangement of the cells and the structure of the envelope, and by the further differentiation of a transverse axis. (3) In *Pandorina* the cells are almost in contact, and in *Volvox* they are actually connected by protoplasmic processes. (4) The beginnings of histological differentiation are also evident in the cells composing the so-called colony. In *Eudorina*, according to Carter (1858), the cells are differentiated into male and female in definite regions, the male cells developing from the anterior quartet and the remainder becoming female; in *Volvox* sexual and asexual reproduction alike are limited to a few of the cells; and in *Pleodorina* the asexual process is confined to the posterior hemisphere. The cells of the organism are thus histologically and functionally differentiated in this particular in these higher genera. Although the degree of differentiation is slight, it is nevertheless appreciable. (5) In the matter of locomotion the activities of the individual cells of the organism are not independent of each other, but are correlated, the flagella acting together to produce rotation, its reversal, or its cessation. The predominance of the direction in the higher genera plainly exhibits the phenomenon of correlated locomotor activities of the constituent cells.

The facts above cited emphasize the desirability of regarding each of these so-called colonial flagellates of the subfamily *Volvocinæ* as a unit, with an organization of its own, and not as a colony, that is, an aggregation of independent and similar cells associated merely as a result of descent from a common parental cell, the form being a matter of chance or circumstance. The group of cells as a whole, and not each of the constituent cells, is the unit of descent, of form, and of func-

tion, and the word colony can be applied to it only by the license of usage and as a matter of convenience.

Reference has been made frequently in the preceding pages to the prevalence of colonies whose symmetry has been disturbed by loss of cells. In most instances only the empty secondary sheath remains, giving no clue to the cause of the loss of its contents. In collections made in Phelps Lake, Havana, Ill., in August 1896, however, colonies were often found which were parasitized by one of the Sporochytriaceæ, which upon examination proves to be *Dangeardia mamillata*, described by Schröder (1898) as a parasite of *Pandorina morum*. As these infested colonies frequently showed a loss of one cell or more and exhibited all stages in the destruction of the cell, it seems probable that the loss was due to the parasite. *Eudorina elegans* and *Pandorina morum* occurred in the same collection and were similarly infested. Two additional genera, *Platydorina* and *Eudorina*, are thus to be added to the list of hosts of *Dangeardia*.

For the convenience of systematists a brief statement of the generic and specific characters of the form herein described is now given, followed by a key to the genera and species of the Volvocinæ for the assistance of students of this interesting and not uncommon group of freshwater organisms. Species not as yet reported to my knowledge from Illinois are indicated by an asterisk when found elsewhere in this continent and by a dagger when not as yet reported from it. It is not at all improbable that all the species here listed will yet be found within this State.

PLATYDORINA, gen. nov.

Colony flattened, the two faces compressed so that the cells of the two sides intercalate; flagella upon both faces on alternate cells. Anterior and posterior poles of major axis differentiated by the arrangement of the cells and by the structure of the envelope. Long and short transverse axes differentiated by the flattening of the colony. Cells similar, biflagellate, each with stigma, chromatophore, and pyrenoid. Asexual reproduction by repeated divisions of all of the cells, each forming a daughter colony.

Platydorina caudata, sp. n.

Colony flattened, horseshoe-shaped, twisted about one eighth of a turn from right over to left; cells 16 or 32,

arranged in a marginal row of 10 or 12 and a central area of 6 or 20; posterior end with 3 or 5 prolongations or tails formed by extension of the common outer sheath.

Known habitat, lakes and streams in Central Illinois. Types in the collections of the Illinois State Laboratory of Natural History and deposited in the United States National Museum.

Keys to the Genera and Species of the Subfamily Volvocinæ.

Cells arranged in cœnobium of definite forms varying with the species, biflagellate, with stigma and one or more chromatophores; surrounded by a gelatinous envelope, whose development separates them to a greater or less degree; number not uniform, varying in the different species, often, but not always, definite. Asexual reproduction by repeated divisions of gonidial cells, which constitute the whole or only a part of the parental organism, to form daughter organisms; sexual reproduction in some species (in others unknown) by the conjugation of male and female gametes, resulting in the formation of a resting stage, which later develops into a new organism.

Genera.

- | | | | |
|---|---|--|-------------------------|
| 1 | { | Cells arranged in form of plate, with flagella upon one face only | 2. |
| | | Cells arranged in spherical, ellipsoidal, or flattened colonies; flagella not confined to one face | 3. |
| 2 | { | Cells in a squarish plate; envelope closely adherent | <i>Gonium.</i> |
| | | Cells in a rounded plate; envelope swollen, oval, or spherical | <i>Stephanosphaera.</i> |
| 3 | { | Colony ellipsoidal or spherical; cells crowded together, conical, reaching towards centre, outer membrane of concentric layers | <i>Pandorina.</i> |
| | | Cells not crowded together nor reaching towards centre of colony | 4. |
| 4 | { | Colonies ellipsoidal or flattened; cells uniform in size | 5. |
| | | Colonies spherical or spheroidal, or, if ellipsoidal, with small vegetative and large gonidial cells | 6. |
| 5 | { | Colony ellipsoidal or spherical; poles not differentiated by arrangement or size of cells or by structure of envelope | <i>Eudorina.</i> |
| | | Colony flattened, horseshoe-shaped, with poles differentiated by arrangement of cells; posterior end with tails | <i>Platydorina.</i> |
| 6 | { | Cells not connected by protoplasmic processes, of two sizes, smaller vegetative at anterior pole and larger gonidial at posterior. | <i>Pleodorina.</i> |
| | | Cells connected by protoplasmic processes, not markedly different in size | <i>Volvox.</i> |

Species.

GONIUM.

- | | |
|------------------|--------------------------|
| } Cells 4 | <i>sociale</i> (Duj.)† |
| } Cells 16 | <i>pectorale</i> , Müll. |

STEPHANOSPILERA.

- Represented by a single species, characterized as follows:—Cells 4 or 8, ovoid or spindle-shaped, with numerous processes *pluvialis*, Cohn.*

PANDORINA.

- Represented by a single species, characterized as follows:—Cells 16 or 32, crowded, each with a single chromatophore and pyrenoid *morum*, Bory.

EUDORINA.

- Represented by a single species, characterized as follows:—Cells 32, 16, or 64, similar, not crowded together; common outer membrane without marked concentric structure *elegans*, Ehrb.

PLATYDORINA.

- Represented by a single species, characterized as follows:—Cells 16 or 32, arranged in a horse-shoe-shaped plate, those of the two faces intercalated. Posterior end with 3 or 5 tails *caudata*, Kofoid.

PLEODORINA.

- | | | |
|---|--|--------------------------------|
| { | Cells 64 or 128; gonidial cells about two to three times the diameter of vegetative cells, which constitute about one half the total number and lie in anterior hemisphere. | <i>californica</i> , Shaw. |
| { | Cells 32, rarely 16 or 64; gonidial cells not more than twice the diameter of the vegetative cells, which constitute the anterior quartet.. | <i>illinoisensis</i> , Kofoid. |

VOLVOX.

- | | | |
|---|--|-----------------------|
| { | Cells about 10,000 (minimum 1500, maximum 22,000), angular, with stout connecting protoplasmic processes into which the chromatophore may enter. Diameter of colony about 700 μ (minimum 400, maximum 1200); diameter of cell-body 3-5 μ | <i>globator</i> , L. |
| { | Cells 500-1000 (minimum 200, maximum 4400), rounded, with slender connecting protoplasmic processes into which the chromatophore does not enter. Diameter of colony 170-850 μ ; diameter of cell-body 5-8 μ | <i>aureus</i> , Ehrb. |

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Urbana, Ill., U.S.A.,
Dec. 5, 1899.

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EXPLANATION OF PLATE VII.*

Abbreviations.

<i>A.</i> Anterior pole.	<i>P.</i> Posterior pole.
<i>c.v.</i> Contractile vacuole.	<i>p.</i> Outer pellicle of protoplasm.
<i>f.</i> Flagellum.	<i>pr.</i> Knob-shaped mass of protoplasm.
<i>m.</i> Matrix.	<i>pyr.</i> Pyrenoid.
<i>n.</i> Nucleus.	<i>s.sh.</i> Secondary sheath.
<i>ncl.</i> Nucleolus.	<i>st.</i> Stigma.
<i>p.sh.</i> Outer or primary sheath.	

Fig. 1. *Platydorina caudata*, face view of 32-cell colony, $\times 550$.

Fig. 2. Face view of 16-cell colony, $\times 628$.

Fig. 3. Edge view of 32-cell colony, $\times 350$.

Fig. 4. Lateral view of one of the marginal cells, $\times 1400$.

Fig. 5, a-e. Outline of the posterior ends of several deformed colonies, $\times 280$.

LXXII.—*On the Luminous Organs of Selachian Fishes.* By
RUD. BURCKHARDT, Nat. Hist. Mus., S. Kensington.

In the 'Zeitschrift für wissenschaftliche Zoologie,' vol. lxvi. 1899, Johann, at the instigation and under the guidance of Prof. Blochmann, of Tübingen, published a paper entitled "Ueber eigenthümliche epitheliale Gebilde (Leuchtorgane) bei *Spinax niger*," in which are given the results of some researches he made in this subject.

In this paper he describes some very minute organs with

* Figures drawn by C. A. Kofoid and inked by Miss L. M. Hart.